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A CLASS BOOK OF
GEOLOGY OF INDIA
FOR JUNIOR STUDENTS

BY

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WITH AN INTRODUCTION

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INTRODUCTION

This little class book of the Geology of India is a very useful addition to the few text books available on the subject. Indian students have felt a great need of an introduction to this youngest but most wonderful of all sciences and I have pleasure in commending this book prepared by my old friend, Mr. N. C. Mittal of Jammu (Kashmir).

The author has briefly described all the geological formations found in our great country, from the lowest to the highest with the predominant rocks, minerals and fossils in the various strata. Here and there a few theories are referred to and a valuable chapter on the mineral deposits with their mode of occurrence and uses is also added. On the whole, the book is acceptable not only to the junior students of Indian Geology but also to the general reader who must needs have some knowledge of the history of the earth in India.

It is a great pity that for so many decades

the studies of geology and of its daughter science geography have been neglected by our Indian Universities. The result is a dearth of skilful Indian geographers and geologists who are so much in demand *to-day* for national reconstruction and Post-War planning. I should be very happy to know that this small volume has led many a young Indian student to a further study of geology and a mastery of the science which is necessarily required in these days.

MANECK B. PITHAWALLA,

20th Nov., 1944.

Victoria Road, Karachi.

DEDICATED

TO

My Dear Friend

Dr RAJ NATH, D. Sc., M. Sc.,
PROFESSOR OF GEOLOGY,
HINDU UNIVERSITY, BENARES.

Preface

As a Lecturer in Geology to Intermediate students preparing for the Punjab University I have realised their great difficulty in mastering Geology of India because of the absence of any elementary book on the subject. I with Prof. R. C. Mehdiratta wrote a book entitled "An Introduction to Geology of India" a few years ago. This too was found by the students too difficult to digest because it was more advanced and contained much more matter than was required for them. This compelled me to re-write the whole keeping in view their syllabus and difficulties. I have written this in an easy style and I have treated the subject in a rather elementary way, of course the matter has been brought upto date. I think this book will be found useful not only by the Junior students but also by the senior students. Our book entitled "An Introduction to Geology of India" was used with great advantage by the Engineering students of the N. E. D. Civil Engineering College, Karachi. Dr. M. B. Pithawalla, D Sc.,

F. G. S., Professor of Geology asked me several times to get the book reprinted which could not be done on account of certain unavoidable circumstances. I am quite sure the present volume too will be found useful by his students. It will also be an interesting reading for those who are interested in the science though they are not students of Geology. Chapter I will be of great interest to them because it contains Physical features of India—geological divisions of India, their characters and peculiarities; mountains, lakes, rivers, coasts, volcanoes, earthquakes and glaciers of India. Chapter XVIII will also be very interesting. It contains information with regard to Economic geology of India e. g., metals and ores; precious and semi-precious stones; economic mineral products; building stones; lime and cements, etc. Besides this, the geological systems have been described broadly giving their geographical distribution, rocks, fossils, outcrops, economics and other peculiarities. In the end I have given questions of the last nine years which were set in the Intermediate Examinations of the Punjab University.

I do not claim any originality for the book. I have gathered information from various sources e. g., Records and Memoirs published by Geological Survey of India, "Geology of India" by D. N. Wadia, "An Introduction to Geology of India" by R. C. Mehdiratta and myself, "A Summary of Geology of India" by Vredenburg and Transactions of the Mining, Geological and Metallurgical Intsitute of India, Volume 39, No. 2 and my personal field experience.

My most sincere thanks are due to Dr. M. B. Pithawalla, Professor of Geology who has very kindly written an introduction to this little book and has been a source of encouragement. My thanks are also due to Mr. S. S. Malhotra, Mining Officer, Jammu for most of the information supplied to me contained in this book with regard to rocks and minerals of economic value in Jammu and Kashmir State. I have also to thank Mr. D. N. Sharma, Basic School, Jammu for drawing the map of India, showing mineral localities.

Jammu,
1-1-1945.

N. C. MITTAL.

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CHAPTER I

PHYSICAL FEATURES

From geological as well as physical point of view India is divided into three main regions :—

(1) The Plateau of the Peninsula (2) The mountaineous region lying to the west, north and east of India known as the Extra-Peninsula (3) The Indo-Gangetic plains of the Punjab, United Provinces and Bengal.

It may be pointed out that there is no resemblance between the *Peninsula* and the *Extra-Peninsula*, the chief points of difference between the two are the following:—

1. *Stratigraphic*, or that connected with the geological history of the areas. A study of the geological formations of the two regions shows that the Indian Peninsula became a land surface after the formation of the Vindhyan System

(Pre-Cambrian) of rocks and has remained so down to the present day. Where as the Extra-Peninsular area remained below the sea from the very earliest time down to the Tertiary era. It became land area during the Tertiary and therefore shows the record of almost all the great geological periods

2. The *Geo-tectonic*, pertaining to the geological structure. The Peninsula has been a stable land mass of great rigidity and strength and has not yielded to any folding or faulting movements. The Extra-peninsula on the other hand, is a weak and flexible portion of the earth's crust and is composed of highly folded and faulted rocks.

3. *Physiographic*, pertaining to physical features. (1) The mountains of the Peninsula are remnants of hard rocks that have withstood denudation of long ages which has completely removed softer materials i.e., they are mountains of *Relic type* or *circum-denudation*, while those of the Extra-peninsula are mountains in true sense

of the word i.e., they have been built of tangential thrusts i.e., mountain-building movements. (2) The rivers of the Peninsula are slow and sluggish i.e., *Mature rivers*, they have reached their base-level of erosion, while the rivers of the Extra-peninsula are young rivers (immature), they are still rapid and torrential in their courses.

The Indo-gangetic plain. From human-point of view it is very important, but from geological point of view it is unimportant. It is composed of sand, silt, clay, etc. (alluvium) brought slowly by young Himalayan rivers and have concealed the solid geology of the region.

Mountains

The most important mountain of India as well as of the world is the H i m a l a y a n mountain.

The classification of the Himalayan mountain-Ranges may be given as follows:—

(1) **Geographical.**—For geographical purposes the Himalayan mountain is divided into three parallel or longitudinal zones—

(a) *The Great Himalayas.*—Their average height extends to 20,000 feet. Peaks like Mount Everest, Kinchinjunga are situated on it

(b) *The Lesser Himalayas or Middle ranges.*—Their average height is 12,000–15,000 feet. Their average width is about fifty miles.

(c) *The Outer Himalayas, or the Siwalik ranges.*—Their average height is 3,000–4,000 feet. They form low hills and lie in-between the Lesser Himalayas and the plains.

2. **Geological.**—As regards geological structure and age, the Himalays fall into three broad stratigraphical zones :—

(a) *The Northern or Jibetan zone.* It lies behind the line of the highest elevation i. e., the central axis corresponding to the Great Himalayas. It is composed of highly fossiliferous marine sedimentary rocks belonging from Cambrian to Eocene ages.

(b) *The Central or the Himalayan zone.* It

comprises most of the Lesser or the Middle Himalayas together with the Great Himalayas and are composed of crystalline and metamorphic rocks with unfossiliferous sedimentary rocks of Purana age.

(c) *The Outer or Sub-Himalayan zone* corresponding to the Siwalik ranges. It is composed entirely of Tertiary sedimentary river-deposits.

The Himalayan mountain is composed of a number of parallel ranges separated by valleys or “*dunes*”. Each range presents a steep escarpment towards the Indian region and a gentler slope towards the Tibetan side. There is a great fault known as the ‘*Main Boundary Fault*’, extending from the Punjab Himalayas to E. Assam Himalayas. The Himalayas greatly *affect* the meteorological conditions of India e.g., rainfall, etc.

The other mountain ranges of the Extra-Peninsula are the Salt-Range, the Hindu-Kush, etc.

The mountain-ranges of the Peninsula are the Aravallis, the Vindhya, the Eastern and the Western Ghats, etc.

Lakes

There are very few lakes of notable size in India and they play very little part in the drainage-system of India.

The principal lakes of India may be given as follows:—

Mansarovar and Rakas Tal are in Tibet; Yamdokchu is in Sikkim; Pangkong, Tsomoriri, the Wular and Dal are in Kashmir. The small fresh water lakes of Kashmir are considered as filled up hollows in the alluvium of the river Jhelum. In Rajputana, the Sambhar lake is the most important. It covers an area of about ninety square miles during the monsoon times. It is a shallow water lake and is very much saltish. The salt of the Sambhar is wind-borne. It is derived partly from the sea-spray from the coasts and partly from the dried up surface of Rann of Cutch. The particles of salt are carried

in land by the prevalent winds and dropped down in the hollow when the velocity of the winds is decreased. The Lonar lake is a deep filled up crater-lake in the district of Buldana in South India. The water is saline containing sodium carbonate and sodium chloride.

Drainage

The drainage systems of the Peninsula and the Extra-peninsula are quite different. The Peninsular rivers have reached their *base-level of erosion*,, their valleys are broad and shallows. The drainage is mature. In the Peninsula almost all the rivers flow towards the east with the Western Ghats as their water -shed.

In the Extra-Peninsula the Himalayan drainage is *antecedent* i.e., it existed before the uplift of the Himalayas; the process of upheaval being so slow that though the rivers were rejuvenated several times they were never forced to leave their channels which from ceaseless erosion developed into gorges. The

river erosion and the uplift of the Himalayas went on side by side. The water-shed of the Himalayan rivers is situated far to the north of the highest peaks of the Himalayas i. e., towards the Tibetan side.

Glaciers

The Great Himalayas are the gathering-grounds for snow and ice and feed a large number of glaciers. The majority of the Himalayan glacier range in size from two to three miles in length but some such as Hispar and Chogo Lungma are twenty four miles long while a few others are forty miles long. The Himalayan glaciers are of the type of *Valley Glaciers*, a few are *Hanging glaciers*.

A few important characters of the Himalayan glaciers are as follows:—

(1) There is large quantity of moraine material on their surface. (2) They are very slow in their movement, their daily motion being three to five inches at the sides and from

eight inches to about a foot in the middle.

(3) Some of them are retreating at their end.

(4) There is considerable amount of sub-glacial and en-glacial drainage.

The mountains of the Lesser Himalayas do not support any glacier at the present day but the records of Pleistocene glaciation are met with in the form of moraines and old silted up glacial lakes.

Denudation

The Indian weather has got a peculiar effect on the denudation of the rocks. Alternate saturation and desiccation has a curious weathering effect on the crystalline rocks of the Peninsula. The felspars of the crystalline rocks have decomposed into hydrated oxide of aluminium which with ferruginous impurities has given rise to laterite. Another product of decomposition of the Deccan-basalt is *Black soil* or *regur*. *Nitre* of Behar is another example. All kinds of weathering agencies have their respective effect

on Indian rocks e. g., frost, snow, ice in the mountainous regions e. g., Himilayas, etc., wind and alternate rise of temperature in Rajputana.

The rivers of the Extra-Peninsula erode very considerably during monsoon months and transport an abundant quantity of alluvium to the sea.

Volcanoes

Active volcanoes are absent in India. There are a few instances of dormant or extinct volcanoes like those of Barren islands in the Bay of Bengal. Now only a truncated remnant of a once much larger cone is seen. The part of the volcano above the water is very small. The base of the cone lies much below the surface of the sea. It was in eruption in 1789.

Earthquakes

A large number of earthquakes have shaken

the Extra-Penisula but none the Peninsula.

Some of the well-known Indian earthquakes are:—Delhi, 1720; Calcutta, 1737; Cutch, 1819; Kashmir and Bengal, 1885; Kangra, 1905; Behar, 1934; Quetta, 1935.

The Kangra earthquake was tectonic in character. It shook very large area and distant places like Sind, Quetta, Afghanistan and the Gangetic-delta were also affected. Geological effect was insignificant, a few land-slides occurred, courses of rivers were disturbed and there was slight alteration of level e. g., Dehra-Dun and the Siwalik hills showed a rise of about a foot relatively to Mussoorie hills.

Behar earthquake of 1934 and Quetta earthquake of 1935 were also tectonic in their origin.

Subsidence and upheaval

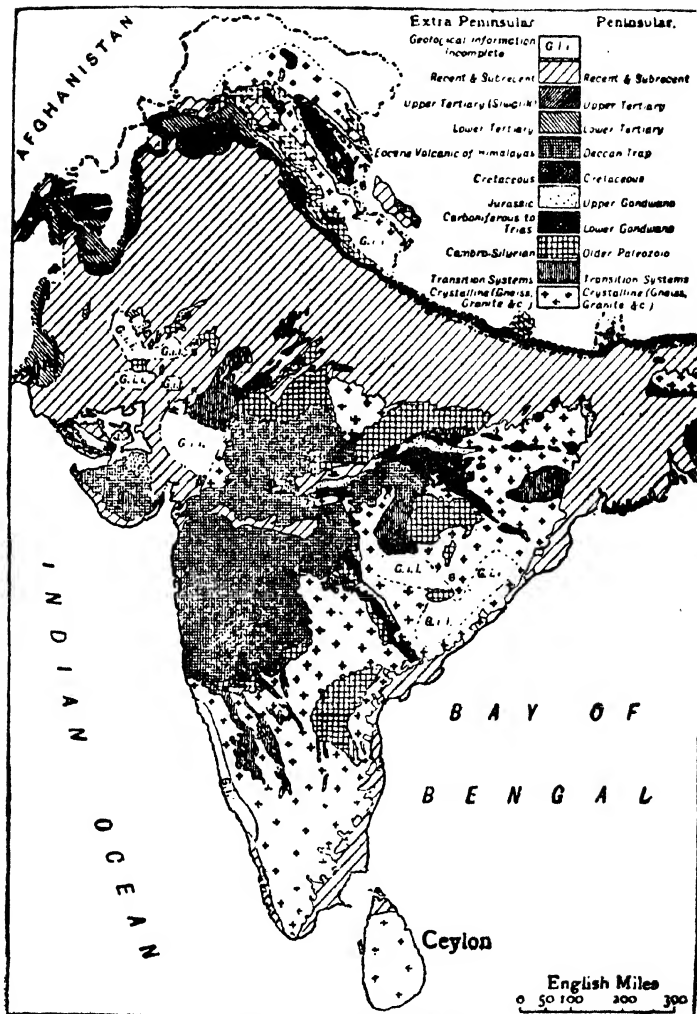
The Peninsula was not affected by earth-movement except at the coasts where raised beaches and marine shells are found at high

elevations beyond the reach of waves and tides. This shows upheaval of the coasts. It is believed that the Himalayas are still rising though very gradually. The movements of subsidence are noted in the Gangetic delta by the presence of peat and lignite deposits in the alluvium and by a submerged forest near Bombay about twelve feet below low-water mark. In 1819, the western border of Rann of Cutch went under the sea and it was accompanied by an elevation of a large tract of land known as the Allah-Bund.

The coasts

The Indian coasts are on the whole uniform and unbroken in character. It is on the Malabar coast that there are a number of lakes and lagoons. The Peninsula is surrounded on both the sides by a platform, the plain of marine denudation which is of greater width on the Malabar coast than on the Coromandel coast. India enjoys very few harbours.

GEOLOGICAL MAP OF INDIA



Courtesy—Prof. G. G. Narko.

CHAPTER II

THE PRE-CAMBRIAN SYSTEM

The Pre-Cambrian rocks are the oldest fossiliferous rocks of the earth's crust. The rocks below the Cambrian system are called the *Pre-Cambrian Rocks* and the time during which they were deposited is called the *Pre-Cambrian period*. The Pre-Cambrian rocks are divided into two sections depending upon the characteristic features of the rocks. The older of the two is called the *Archæan* which means very old. The Archæan rocks are the oldest rocks of the earth's crust and form a foundation of all the succeeding sets of rocks. In whatever part of the world we meet with the Archæan rocks they show practically the same characteristic features. They are highly metamorphosed gneisses and schists. The gneisses show gneissic structure, while schists show schistose structure. They are devoid of fossils and therefore they cannot be correlated with the Archæan rocks of the

different countries of the world. We do not know the exact conditions under which they were deposited. It is, however, believed that they were originally sedimentary and Igneous rocks and were metamorphosed later on into gneisses and schists. The original structures and textures were destroyed. The younger section of the Pre-Cambrian rocks lies over the Archæan rocks and consists of sedimentary rocks like sandstones, limestones, and conglomerates

They contain very few fossils and those also of very low type and therefore difficult to correlate them with the rocks of the other countries.

The Pre-Cambrian rocks of India may be classified as follows:—

General classification of Pre-cambrian rocks.		Classification of Pre-cambrian of the Peninsula (India).	
Younger series	} Torridonian Algonkian	Purana group or era	} Vindhyan System Cuddapah System Dharwar System
Archæ-an	} Huronian Lewisian	Archæ-an group	} Gneisses and schists.

CHAPTER III

THE ARCÆAN SYSTEM

It constitutes the oldest rocks of the earth's crust which form foundation of all the succeeding sets of rocks. They are thoroughly crystalline, folded and faulted. They usually show banded structure. They are devoid of fossils.

They are widely distributed in India. They cover *very large part of the Peninsula*, Orissa, Central Provinces and Chota Nagpur. They are also found in Bundelkhand, Baroda, Aravallies and in the Himalayas.

The most important rock of the Archæan system is the *Gneiss*. It varies in composition from granite to gabbro. It consists of orthoclase, microcline, quartz, muscovite, biotite, and hornblende. It shows gneissic structure. Next important rock is the *schist*. It has the same composition as the gneisses but felspars. Less common rocks are marbles, dolomites, graphite, etc.

There are some petrological types which are found associated with the Archæan gneisses and schists:—

Elæolite-syenite, Augite-syenite and corundum-syenite of the Coimbatore district.

Charnockite of Madras and Bengal. It is a granite consisting of orthoclase, plagioclase, quartz, garnet, hypersthene, and iron ores. It is an important rock type of the Peninsula. It is named by Holland from Charnock, the founder of Calcutta.

Gondite.—It is a metamorphosed rock consisting of quartz, manganese garnet and rhodonite. It is named from the Gonds of the Central Provinces by Fermor.

Kodurite.—This is a Plutonic rock consisting of orthoclase, manganese garnet and apatite. It is named from Kodur in Vizagapatam district.

Khondalite.—Gneisses and schists, composed

of quartz, sillimanite, garnet and graphite and are named after the Khonds of Orissa.

Calc-gneisses and marbles.

The Archæan rocks of India are classified into three groups:—

(1) *Bengal gneiss*—Highly foliated gneisses and schists of Bengal, Behar, and Orissa. It is found covering large tract of the Peninsula. The schists and garnetiferous gneisses of South India known as Fundamental gneiss or Peninsular gneiss belong to this class. It is considered to be the oldest member of the Archæan rocks.

(2) *Bundelkhand Gneiss*—It occurs in Bundelkhand and in the Peninsula. It is a granitoid gneiss resembling a pink granite in hand-specimen. It is devoid of banded structure. Bundelkhand gneiss is traversed by dykes, sills and veins on an extensive scale. It is quarried largely for use as a building-stone.

(3) Charnockite series (Nilgiri gneiss)—It is

massive eruptive dark coloured hypersthene granitoid gneiss of South India. It is typically developed in the Madras Presidency. Its constituents are Plagioclase, blue coloured quartz, augite, hypersthene, enstatite, garnet, iron ores, and graphite.

The Archæan of the Himalayas—The Archæan rocks are also found in the Central core of the Himalayas. It consists of Central or Himalayan zone.

CHAPTER IV

THE DHARWAR SYSTEM

The Dharwar rocks are typically developed in the *Dharwar area* of the Peninsula. Besides this, they are developed in the Aravallies, Central Provinces, etc. They are also developed in the Himalayas e. g., Simla, Spiti, Kashmir, etc.

The outcrops of the rocks of the System show the appearance of elongated strips parallel to one another.

The schists are the most important rocks. Slates, Phyllites, and marbles are also found. The schists contain Hæmatite, Banded Jaspers, flexible sandstones, and igneous rocks are also met with. Almost the whole of the manganese ores of India are associated with the Dharwar rocks e. g., Kodurite series, Gondite series, and lateritic deposits.

The Himalayas.—The Dharwar system of rocks are also met with in the Himalayas e. g., Spiti, Kashmir, Simla, Gharwal, and Darjeeling.

The rocks of Dharwar system are economically the most important :—

(1) Ores of gold, manganese, iron, Copper and lead are found.

(2) The Industrially useful minerals like muscovite, corundum and valuable minerals like Pitchblende (radio-active mineral) are also found.

(3) Gem-stones and semi-precious stones like beryl, garnet, tourmaline and quartz are also met with.

(4) Building-stones like marbles, granites, slates are also found in great abundance.

The age of the Dharwar system is *Huronian*.

CHAPTER V THE CUDDAPAH SYSTEM

The Purana group or era includes the Cuddapah and the Vindhyan systems.

The Cuddapah System.—It is the older of the two systems of which the Purana is composed. It lies unconformably over the Dharwar system.

It is typically developed in the Cuddapah district of the Madras Presidency from which the system has derived its name. It is also developed in the Eastern ghats and Central Provinces.

The outcrops of the rocks are of a broad crescent-shaped.

The rocks consist of thick series of quartzites, slates and limestones. Gneisses and schists are not found. A few lava flows and dykes are also found at Gwalior and Bijawar.

The rocks are unfossiliferous.

The Cuddapah system is divided into two sections with a great unconformity in between the two.

It is economically important. It contains iron and manganese ores, slates, bright coloured Jaspers and cherts.

The age of the system in term of American stratigraphy is Algonkian.

CHAPTER VI

THE VINDHYAN SYSTEM

It is the younger of the two systems of which Purana is composed.

The system derives its name from the Vindhyan mountains where the rocks are typically and extensively developed. It covers an area of about 40,000 square miles.

The system is composed of two distinct facies of deposits. The lower part is composed of argillaceous and calcareous deposits e.g., thin bedded shales and limestones and the upper part is composed of arenaceous deposits e. g., fine grained sandstones showing mottled appearance. A few beds of conglomerates are also found which contain diamonds for which India was famous. The Panna and the Golconda diamonds were obtained from these conglomerates.

The rocks of the system show very little

disturbance. They show horizontal deposition of sediments over large area. The rocks are not metamorphosed but they are indurated or compacted. The Vindhyan sandstones show that they were deposited in shallow-water. In Rajputana Malani rhyolites covering many thousand of square miles of area are found. A few obscure traces of animal and vegetable life are found. A few discs, remains of some primitive brachiopods, and fucoid markings are seen.

In **Extra-Peninsula** the rocks of the system are seen at Simla, Peshawar. Darjeeling and Hazara.

The sandstones are used for building purposes and limestone for cement making. Diamonds are gem-stones which are used for ornaments.

The age of the system is Torridonian.

CHAPTER VII

THE CAMBRIAN SYSTEM

Before giving the description of the Cambrian System, it is desirable to give the general characteristic features of the Palæozoic era which are as follows:—

The Palæozoic era includes that portion of the earth's history which contains the earliest known fossils both of plants and animals. It is sub-divided into two eras—the older Palæozoic which includes the periods of Cambrian, the Ardovician and the Silurian System. The Newer Palæozoic includes the Devonian, the Carboniferous and the Permian. The Older Palæozoic era is characterised by the abundance of trilobites, graptolites, and brachiopods and absence of vertebrate remains except in the highest parts of the Silurian. The Newer Palæozoic rocks include fishes and amphibians in large numbers. Graptolites are absent, trilobites decrease in number, flowerless plants increase in number,

corals, crinoids, and nautiloids (cephalopoda) continued in increasing numbers throughout the era. The Devonian period is called the *age of fishes* and the Carboniferous contains the largest amount of coal.

The Palaeozoic rocks of India

They are found in the Salt-Range, Kashmir, and the Himalayas. They are marine fossiliferous rocks. They consist of sandstones, shales, slates and dolomites. The principal fossils are brachiopods, corals and trilobites.

The rocks from Cambrian to Carboniferous systems of India are included in *the Dravidian group* or era.

In India there is a great unconformity in between the Vindhyan System and the Cambrian System of rocks.

The Cambrian System

The Cambrian System in India is

developed in the Salt-Range, Spiti, and Kashmir.

The Salt Range. The Cambrian System is very well developed in the Eastern Salt-Range near Khewra and a section is exposed there. The order of succession of beds is as follows:--

5. Salt-pseudomorph shale.
4. Magnesian sandstone.
3. Neobolus shale.
2. Purple sandstone.
1. Salt-marl.

(1) *Salt-marl*.—It is a calcareous clayey deposit of brick red colour enclosing beds of rock-salt of great thickness and lateral extent. Large masses of gypsum and dolomite are also interbedded.

The origin and age of the Salt-marl, rock-salt, etc., of the Eastern Salt-Range near Khewra and greyish clay, gypsum and rock-salt of its Western extension near Kohat which constitute the *Saline series* are debatable points.

They are believed to be of Lower Cambrian or Lower Tertiary in age.

(2) *Purple sandstones*.—The next member of the Cambrian system is a sandstone of purple colour called the Purple sandstone which lies over the Salt-marl with a very unbroken Junction (unconformity). It is intercalated with shales at places. The sandstone is a shallow-water deposit. It is either of Lower Cambrian or Lower Tertiary in age.

(3) *Neobolus bed*.—Lying over the Purple sandstone is a series of dark to grey coloured micaceous shales with a few dolomitic layers. The bed is named Neobolus bed after the important brachiopoda fossil—Neobolus. Other fossils present are trilobites—Redlichia and gastropoda—Hyolithes.

(4) *Magnesian sandstone*.—The Neobolus shales are succeeded by fine grained dolomitic sandstones of cream colour. A mollusc and a few annelid tracks are found.

(5) *Salt-pseudomorph shale*.—It lies over the magnesian sandstone. It consists of green to bright red coloured beds of shales and fine grained sandstones. It is a shallow-water deposit. It contains along planes of stratification and lamination cubes of clay which seem to have replaced crystals of rock-salt. It is unfossiliferous. It is the topmost member of the Cambrian system.

Spiti. The Cambrian rocks of this region lie over the the Dharwar rocks with an unconformity in between the two. The system is designated as *Haimanta System* and consists of quartzites, dolomites, slates and conglomerates. It is highly fossiliferous containing trilobites and brachiopoda.

CHAPTER VIII

THE SILURIAN SYSTEM

The Silurian rocks of India are found in Spiti and Kashmir.

Spiti. Over lying the Cambrian rocks in Spiti are found the Silurian rocks consisting of unfossiliferous red coloured quartzites, grits, conglomerates, limestones, and calcareous shales. The limestones contain fossils e. g., trilobites, corals, brachiopods, and gastropods.

Kashmir. The Silurian rocks are very well developed in Kashmir. They are fossiliferous. The rocks are devoid of corals. The other fossils are nearly the same as in the Silurian rocks of Spiti.

THE DEVONIAN SYSTEM

The rocks of Devonian system in India are developed in Spiti and Kashmir.

Spiti. Here the Devonian System of rocks lie over the fossiliferous Silurian rocks. They are composed of unfossiliferous quartzites and are known as *Muth-quartzites*.

Kashmir. In Kashmir, a quartzite similar to that of Spiti is represented by an enormous thickness of strata at places.

The Carboniferous System

The Carboniferous rocks of India are developed in Spiti, Kashmir, and the Salt-Range.

Spiti.—In the type area, the Spiti, the Muth quartzite of Devonian age is overlain by a thick deposit of alternating limestones and quartzites with a few shale beds. The limestones are dark coloured and are highly fossiliferous, the important fossils being Brachiopods (*Productus*, *Spirifera*, *Syringothyris*, and *Athyris*); Lamellibranchs (*Aviculopecton* and *Conocardium*); Gastropods and Trilobites (*Philipsia*). The shales on account of presence of numerous impressions of *Fenestella*—a polyzoa—are known as *Fenestella shales*. These are succeeded by a glacial Boulder-bed and which in turn is succeeded by a fossiliferous calcareous sandstone of Upper Carboniferous age.

Kashmir.—The rocks consist of thin bedded, grey coloured flaggy limestones and are richly

fossiliferous. The majority of the fossils are brachiopods (Productus, Athyris) Syringothyris cuspidata is the index fossil of the series. Age—Lower Carboniferous.

The lime-stones are succeeded by quartzites and shales—bear innumerable impressions of Fenestella (Palyzoa) and are known as *Fenestella shales*. Age—Middle Carboniferous.

At the close of the Middle Carboniferous, the conditions of marine sedimentation gave place to an outburst of volcanoes of violent type which poured out large quantities of lava on the surface. The volcanic rocks consist of two series of rocks, the lower which consists of the *Panjal Agglomeratic Slates*, they have been named as such on account of their extensive development in the Pir Panjal-Ranges. It is composed of a fine textured matrix enclosing small and big angular grains of quartz, porphyries and tourmaline granites. These are succeeded by bedded lava-flows of great thickness and of andesitic composition and are known as the *Panjal Traps*. Amygdaloidal

and porphyritic structures are common. Glomero-porphyritic structure is typically developed.

The Salt Range

The Salt-pseudomorph beds of the Cambrian age are unconformably overlain by a Glacial *Boulder-bed*. It is composed of boulders of various sizes and of different composition, all bearing marks of glacial erosion—facetting, striations, and polishing. Some of the boulders are of granites and others are of rhyolites and quartzites. They have been joined together by a fine dark coloured silty matrix.

The Boulder-bed is succeeded by *Speckled sandstones*. The age of both the formations is Upper Carboniferous.

CHAPTER IX

THE PERMIAN SYSTEM

All the rock formations of India begin-

ning with the Upper Carboniferous and ending with the Recent are included in the *Aryan group* of rocks.

The marine Permian rocks in the Extra-Peninsula are found in the Himalayas and the Salt-Range.

The Himalayas (Spiti)

The fossiliferous calcareous sandstones of Upper Carboniferous age are overlain by carbonaceous shales known as *Productus shales* of Permian age. The Brachiopods are the most important fossils which are represented by a large number of genera e. g., *Productus*, *Spirifer*, and *Dialasma*.

The Himalayas (Kashmir)

The Permian rocks are largely developed in the Kashmir Himalayas consisting mostly of limestones known as *Zewan series* from their occurrence near the village of Zewan in the Vihi district. They contain large number of brachi-

opods such as are found in the Salt-Range and Spiti e.g., *Productus*, *Spirifer* (*S. Rajah* is the most common), *Marginifera*, *Lyttonia*, *Spiriferina*. The Lamellibranchs are also found. The base of the Zewan series consists of shales containing large number of *Protoretepora* (Polyzoa).

The Salt-Range

The Speckled sandstone of Upper Carboniferous age is conformably overlain by a great thickness of limestones known as *Productus limestones*. It is one of the most extensively developed formation of the Salt-Range.

The *Productus* limestone is chiefly composed of dark coloured limestone with a few carbonaceous shales at the base. The limestones are at places dolomitic and contain cherty nodules. The *Productus* limestone is primarily a crinoidal limestone, being very rich in the broken stems and plates of crinoids. There are marls at places.

The fauna of the *Productus* limestone is very

rich and may be given as follows:—

Brachiopods are found in very large numbers e.g., *Productus*, *Spirifera*, *Spiriferina*, *Athyris*, etc. Crinoids are also found in large numbers e.g., *Poteriocrinus* and *Cyathocrinus*, Gastropods (*Bellerophon*, *Euomphalus*, *Pleurotomaria*), Foraminifera (*Fusulina*) are in abundance. Lamellibranchs (*Lucina*, *Cardinia* are also found).

Polyzoa (*Fenestella*) and corals (*Pachypora* are common.

A beautiful section of the *Productus* limestone is found along the Bakkh ravine near Musakhail in Mianwali district in the Punjab.

There is no *unconformity* between the rocks belonging to the Carboniferous and Permian systems of the Salt-Range, Spiti, and Kashmir and there is a clear resemblance between the fossils of these two systems of rocks in these areas, so the system is named here as the *Pemo-Carboniferous* or the *Anthracolithic System*.

CHAPTER X

THE TRIASSIC SYSTEM

Before giving the description of the Triassic System of India, it is desirable to know the general characteristic features of the life of the Mesozoic era which may be given briefly as follows:—

The Mesozoic life differs in many respects from that of the Palæozoic life. Many of the characteristic Palæozoic remains of life are absent in the Mesozoic e. g., graptolites and trilobites. Brachiopods and crinoids become less in numbers during the Mesozoic. Echinoids and lamellibranchs become a dominant fauna during the Mesozoic. The following types of lives are very characteristic of the Mesozoic era:—

1. The ammonites and belemnites.
2. The reptiles : They become very abundant both in numbers and forms. Some lived on land, some in sea, while others

flew in air. Some of them were herbivorous while others were carnivorous. Some of the most important reptiles of the time are Ichthyosaurus, pleisiosaurus, and atlantosaurus. The Mesozoic era has been called *the age of reptiles*. For the first time in the history of the earth the remains of birds known as Archiopteryx are found. In the Mesozoic the flowering plants appear and in the uppermost part of it, the existing types of plants appear.

The Triassic System

The marine Trassic rocks of India are well-developed in the Himalayas (Spiti and Kashmir), the Salt-Range and Baluchistan.

Spiti

The Triassic System of Spiti is also known as *Lilang system*. The Triassic rocks are developed along the whole northern boundary of the Himalayas. They are developed on large scale in Spiti and adjoining provinces

of Kumaon and Gharwal.

The system mostly consists of dark-coloured limestones and dolomites with intercalations of blue coloured shales.

As regards Triassic fauna, large number of ammonites e.g., otoceras, ophiceras, meekoceras, hedenstroemia, and ceratites are found. Next in importance to ammonites are lamellibranchs—Daonella and Halobia, and brachiopods—Spiriferina, Spirigera and Rhynchonella.

Kashmir

The development of the Trias rocks in Kashmir is on much the same scale as in Spiti. They are composed of blue limestones and dolomites. An outcrop of the formation is seen on the North-east flanks of the Pirpanjal.

Fossils: Ammonites—Xenodiscus, Ophiceras (O. Sakantula), Hungarites, Sibirites, Kashmir-

ites, Lamellibranch—Pseudomonotis. Brachio-pods—Spiriferina, and Rhynchonetta.

Baluchistan

The rocks are several thousands feet of shales and slates with inter calations of limestones containing lamellibranehs (monotis) and ammonites (didymites and halorites).

The Salt-Range

The system is developed in the Western part of of the Salt-Rcnge. It is found lying over the Productus limestones belonging to the Permian in age. In the Salt-Range the Lower and the Middle Trias are developed. On account of abundance of fossil ammonites, genus *ceratite*, the Lower Trias of the Salt-Range is known as *Ceratate beds*.

They consist of flaggy limestones, grey limestones, and marls. Besides Ceratites, other ammonites are Ptychites, and Flemingites. Other fossils are Rhynchonella, Terebratula and Bellerophon. The Ceratite beds are succeeded

by *Middle Trias Strata* composed of sandstones, crinoidal limestones and dolomites which are full of cephalopods. A beautiful section of this system is exposed along Bakkh ravine near Musakhail in Mianwali district.

After the Middle Trias there comes a stratigraphical gap in the continuance of the Salt-Range deposits.

CHAPTER X

THE JURASSIC SYSTEM

The marine Jurassic system of rocks in India are developed in the Himalayas (Spiti and Kashmir), Baluchistan, the Salt-Range, Cutch, and Rajputana.

The Himalayas (Spiti)

The Triassic rocks are conformably overlain by the Jurassic limestones of a great thickness. They are known as the *Great limestones* or the *Kioto limestones*. They are highly fossiliferous containing Lamellibranchs and Belemnites.

The most important rocks of this system are a series of shales, highly fossiliferous and are known as *Spiti Shales* lying directly over the Kioto limestone. They are 300 to 500 feet thick and are very widely distributed. The shales are mostly micaceous and contain calcareous concretions with ammonites as their nuclei.

Important fossils of Spiti shales may be given below:—

Ammonites—Phylloceras, Lytoceras, Perisphinctes, etc. Lamellibranchs—Pecten, Lima, Avicula, Trigonia. Gastropods—Cerithium. Belemnites are also found.

Kashmír

The rocks are found in central and southern parts of Ladakh, Baluchistan and Jammu State.

Ladakh

It consists of thick dolomitic limestones. Spiti shales are black thin bedded, micaceous

carbonaceous shales full of fossils like magalodon, avicula, pecten, cerithium, some ammonites—macrocephalites and a few fragments of Belemnites.

The Jurassic rocks are also developed at *Banihal* on the Pirpanjal and *Verinag*. They consist of limestones, shales and sandstones and contain characteristic Jurassic fossils but the Jurassic rocks of *Jammu* are devoid of fossils.

Baluchistan

The rocks consist of massive, crinoidal and oolitic limestones. They are found near Quetta. They are fossiliferous in their upper part containing ammonites e. g., macrocephalites.

The Salt Range

The rocks consist mostly of sandstones. A few shale beds, lignite, and limestone are also found. Fossils are also found e. g., plants (*Ptilophyllum*), Belemnites, gastropoda (*Natica*), etc. *Age—middle Jurassic*. The Upper Jurassic rocks are more calcareous consisting of limestones and

arenaceous shales containing fossils of Lamellibranchs e.g., lima, ostrea, pecten, Gastropods e.g., cerithium and also ammonites.

Cutch

The Jurassic rocks are developed here on an extensive scale, their thickness being about 6000 feet. They consist of sandstones, clays, and limestones, richly fossiliferous.

The Jurassic rocks of Cutch include four series—Patcham, Chari, Katrol, and Umia, in ascending order, ranging in age from Lower Oolite to Weald.

Umia series	Weald.
Katrol ,,	...	Upper Oolite.
Chari ,,	Middle. ,,
Patcham ,,	Lower ,,

The fossils are principally ammonites, and lamellibranchs, other fossils are belemnites, nautilus and plants. *More than one hundred species of ammonites* are found. They are represented by perisphinctes. phylloceras. oppelia, and

harpoceras.

Rajputana

The rocks mostly consist of sandstones, grits, conglomerates and limestones—highly fossiliferous, outcrops of which are seen at Bikaner and Jaisalmer.

CHAPTER XI

THE CRETACEOUS SYSTEM

The marine Cretaceous rocks of India are developed in the Peninsula, Narbada Valley, and the Extra-Peninsula—Himalayas (Spiti and Kashmir), Sind, Baluchistan and the Salt-Range.

The Peninsula (The Coastal System)

The Cretaceous rocks were developed along the Coromandal coast by a transgression of the sea. An important outcrop of the rocks is seen at Trichnopoly where it covers a large area. Four stages are recognised in the rocks e. g., Utatur, Trichnopoly, Ariyalur and Ninyur stages.

The rocks of the system are mainly arenaceous and argillaceous. False bedded grits, sandstones and clays are abundant. Shelly limestones are also found. The rocks are highly fossiliferous.

The lowest or *Utatur stage* includes a coral limestone, probably an old coral reef. The fossils are brachiopoda—*Terebratula*, corals and gastropoda. Ammonites and lamellibranchs are very abundant. A few fragments of fossil wood are also found.

The Trichnopoly stage.—Besides fossils of ammonites and lamellibranchs (*Pecten*, *trigonia*, *pinna*, *ostrea*) a few remains of reptiles (*Dinosaurs*) are also met with in this stage.

The *Ariyalur stage* is the most fossiliferous and includes ammonites—*Baculites*, *pachydiscus*; lamellibranchs—*exogyra*, *gryphæa*, *cardita*, *modiola*. Gastropods are abundant. Corals, echinoids, polyzoa and reptiles—*Magalosaurus* are also found.

The Uppermost or *Ninyur stage* contains fossils *Nautilus Danicus*, *Nerinea*, *Orbitoloides*, and gastropods.

The Narbada Valley.—The rocks are marine and are known as *Bagh beds* and consist of limestones and marl. The top members are fossiliferous. The fossils are chiefly lamelli-branches, echinoids, gastropods and corals.

The Lameta Beds.—These are *fluviatile* representatives of the Cretaceous system as developed in Central Provinces and Central India. The rocks are mostly cherty and siliceous limestones, sandstones and clays containing a few fresh water gastropoda e. g. *Physa brincipii*, paludina and a few reptiles.

The Extra-Peninsula

The Himalayas (Spiti).—Lying over Spiti shales of Jarassic age are found *Giumal sandstones* consisting of sandstones and quartzites, containing fossils of ammonites and lamelli-branches—*Cardium*, *Ostrea*, *Arca*. They are

overlain by *Chikkim limestone*, a white fossiliferous limestone containing belemnites, foraminifera, lamellibranchs (*Hippurites*). This limestone is in turn succeeded by unfossiliferous sandstone and shale known as *Flysch*.

Kashmir.—White unfossiliferous limestones belonging to Chikkim series are found in Rupshu Province, *Kashmir*.

Sind and Baluchistan

The rocks consist of limestones and sandstones containing belemnites, lamellibranchs—*cardita beaumonti*, hippurites; and echinoids.

The Salt-Range

The rocks are developed on a small scale in the Trans-Indus extension of the range and the Chichali range. They are composed of white and yellow sandstones and shales. The intercalated black shales contain ammonites belonging to the genus *Perisphinctes*.

The Peninsula (The Deccan Trap)

During the latter half of the Cretaceous

period an enormous quantity of lava welled out in the Peninsula that spread over a vast area and formed a thickly bedded formation known as the *Deccan Trap*. The liquidity of the lava and very great volume in which it was produced gave rise to a plateau topography covering all the previous inequalities of the country. The thickness of the Trap is very great and it reaches to nearly 10,000 feet along the coast of Bombay. The remarkable feature of the lavas is their persistent horizontality throughout their wide area of distribution.

The eruption appears to be of the *fissure type*—welling out of the lava quietly through linear fissures. The fragmentary products are rare. The eruptions were *subærial*.

It is principally a *basaltic lava*. Its texture is fine grained and contain phenocrysts of plagioclase. Prismatic or columnar Jointing is observed at places, which has given rise to step-like, stair-like or *ghat-like* appearance to the lavas, and it is for this reason that

the term "*traps*" meaning steps in Sweedish language is applied to the Deccan Basalts.

A few thin beds of sedimentary origin are intercalated between the lava-beds and are known as *intertrappean beds*, showing that the eruption was not continuous. They are fossiliferous containing plant remains, fresh water mollusca, insects, crustacea, fishes, frogs, tortoises, etc. The most important and common shell is *Physa prinsepia*—a fresh water gastropoda.

The basalts are largely employed as road-metal and building stone. Agates and carnalians found in basalts are used as semi-precious stones. The soil produced by the subærial decomposition of the basalt is a rich agricultural soil. This when mixed up with humus and other organic matter gives rise to the *black-soil*, regur or the well-known Cotton-soil.

CHAPTER XII

THE GONDWANA SYSTEM

The rocks are of *fresh water in origin* rang-

ing in age from the Upper Carboniferous to the Lower Cretaceous developed in the Peninsular India.

The ancient Gondwana land.—The Gondwana System of rocks are also found in Australia, South Africa, South America, and Madagascar. The rocks similar to the Talchir Boulder bed of South India have been found in these countries. The plant fossils and vertebrate remains similar to those of Gondwana rocks of India have also been found in these countries. This similarity and in some cases identity of fossils lead us to infer that there was a land connection between Australia, South Africa, South America and South India for the migration of plants and animals from one place to another. To this connected land mass the name of *Gondwana land* has been given its name from the ancient Gond Kingdoms South of the Narbada in South India where the formation was first discovered. This land came into existence in the upper Palæozoic and continued in existence during the Mesozoic era. It was during the end

of the Mesozoic that the Gondwana-land broke up and portions of land were submerged underneath the sea.

The Gondwana System

The rocks of the Gondwana system have been calssified as follows:—

Upper Gondwana System.	{	Umia Jabalpur Series.	Lower Cretaceous and Jurassic.
		Mahadeva series.	Jurassic.
Lower Gondwana System.	{	Panchet srs.	Trias.
		Damuda „	Permian.
		Talchir ..	Up. Carboniferous.
		Glacial Boulder-bed at the base.	„

The Lower Gondwana System

At the bottom consists of a *Boulder-bed* of fluvio-glacial origin. It is named as the Talchir Boulder-bed after the village Talchir in Orissa. It contains the characteristic glaciated, striated and facetted boulders of rocks embedded in a fine silty matrix which suggest *fluvio-glacial*

agency of transport. Age is Upper Carboniferous.

Over this Boulder-bed lies the *Talchir series* of rocks named after the Talchir district of Orissa of Up. Carboniferous age. It consists of shales, sandstones, grits, conglomerates and coal. The sandstones are felspathic but the feldspars are undecomposed. There are a large number of plant fossils e. g., *Gangamopteris* and *Glossopteris*. The former are found in very large numbers, not less *eight species of this fern* are found. Other plant fossils are *Vertebraria* and *Voltzia*.

Over the Talchir series are found the *Damuda series* of Permian age. It consists of sandstones, shales and oxides and carbonates of iron and coal of good quality. The sandstones are felspathic but the feldspars are decomposed. Many of the coal-fields of Damuda series are traversed by dykes and sills of ultrabasic rocks e. g., mica-peridotite and dolerites. The Damuda series of rocks are very rich in plant fossils. *There are sixteen species of Glossopteris* and *Vertebraria* and four species of *Gangamopteris*. Other plant fossils are

Sphenopteris, Phyllothea, Cardaites, etc. Both the Talchir series and the Damuda series are widely distributed e. g., in Rajmahal Hills, Son and Narbada valleys, Satpura and Godavari valleys.

Over the Damuda series lies the *Panchet series* of Triassic age. It consists of white and greenish felspathic sandstones, shales, red clay and grits. No coal bed is found. Large number of vertebrata fossils are met with. There are amphibians—Gonioglyptus, Glyptognathus; reptiles—Dicynodon. Plant fossils are not found.

The rocks of the Panchet series are found at Satpura and Godavari valleys, They are of restricted distribution.

The Damuda series of the Lower Gondwana System is the principal source of coal in India, contributing nearly 97 per cent of the total annual production. It may fitly be called the coal-bearing series of India. The impor-

tant coal-fields are of Bengal—Raniganj, Jharia and Giridih.

The Upper Gondwana System

The Mahadeva series of Jurassic age lies over the Panchet series of Trias. It derives its name from Mahadeva hills of Satpura. In its lower part it consists of dark basalts and dolerites interstratified with clays and sandstones. The basalts are porphyritic and amygdaloidal. Mica-peridotites are also found.

In its upper part it consists of sandstones, shales and limestones. The most important plant fossils are cycadacæa—*Ptilophyllum acutifolium*, confers, ferns, and equisetum. In the upper part of the series there are found remains of fishes and reptiles.

The Umia-Jabalpur series of Jurassic to Lower Cretaceous rests over the Mahadeva series. The lower part of the series consists of massive sandstones, shales, coal and lignite. The last two rocks are economically of very little value.

In the upper part, it contains marine conglomerates, sandstones, and shales together with sandstones and shales of fluviatile origin, The plant fossils are cycads, conifers, and equisetum.

A few outcrops of Upper Gondwana age are found along the *Coromandel Coast* at Rajahmundari, Ongole, Madras and Cuttack. They are found interstratified with marine fossiliferous rocks that contain lamellibranchs (*Trigonia*) and ammonites (macrocephalites).

The highest beds of Upper Gondwana are also found in Cutch, at a village named Umia from which the series derives its name. They rest over the marine Jurassic rocks of Cutch already described. They are found interstratified with marine conglomerates, sandstones and shales containing ammonites and lamellibranchs of Upper Jurassic to Lower Cretaceous.

Umia beds have yielded large number of plant fossils and the remains of a reptile named *Pleisiosaurus Indica*. It had very long neck.

Cuttak sandstones are used for building purposes, clays for ceramic industries, coarse grained sandstones and grits for millstones, limestone for cement, and hæmatitic and limonitic shales are used for smelting iron.

CHAPTER XIII

THE TERTIARY SYSTEMS

We now come to the third great era in the Indian geology—The Tertiary era. It is interesting to note that there exists no sharp break or divisional line between the Mesozoic and the Tertiary groups of rocks in India like the one so prominently exhibited between the two groups in other parts of the world. There is, however, a remarkable change in the fauna, a '*life-break*' as we may term it existing between the two groups of rocks in India as in Europe. With the commencement of this new period, the cephalopods, so prominently existing during the Mesozoic times, suffered a good deal by the loss of their many genera and species, while belemnites and ammonites died out

altogether, gastropods—an insignificant class of animals in the Palæozoic and the Mesozoic periods reached their climax in the Tertiary periods. The Mesozoic reptiles disappeared and the mammals made their appearance and are found in very large numbers.

An event of a far greater importance that happened during the Tertiary was the breaking up of the old Gondwana continent, large portions of which sank below the seas. It was during these times that the present configuration of the country was given rise to.

An occurrence that perhaps exceeds those mentioned above was the uplift of the Himalayas from the bottom of the Tethys in three intermittent stages during the Tertiary era. The first uplift came off about the middle of the Eocene period, the second in the middle of the Miocene times and the third the final stage during the Pliocene times.

The Peninsula remained a land surface during whole of the Tertiary era and the

marine rocks in the interior of the country are not to be found except at the fringes where the occasional transgressions of the sea gave rise to local deposition of marine rocks.

In the Extra-Peninsula the Tertiary rocks are very well deposited at Sind, Baluchistan, the Salt-Range, the Outer Himalayas (Punjab, Kashmir, Kumaon and the Simla region).

The Tertiary deposits of Sind are typically exposed in the hills of Kirthar, Laki, Suleiman, etc. The Tertiary sequence of Sind is, by reason of its exceptional development, taken as a type for the rest of India for systematic purposes. The following table gives an idea of the principal characters of the stratigraphical sequence, petrology and fossil contents :—

Sind.

<p>Manchhar series 10,000 ft.</p>	<p>Upper Manchhar—grey sandstones and conglomerates. Middle Manchhar—brown and orange shales and clays, unfossiliferous.</p>	
<p>Gaj series 1500 ft.</p>	<p>Lower Manchhar—conglomerates containing teeth of <i>Dinotherium</i>, <i>Mastodon</i> and <i>Rhinoceros</i>. Manchhar series are <i>fluvial</i> or <i>suberially</i> deposited rocks.</p>	<p>Pliocene.</p>
<p>Nari series 6000 ft.</p>	<p><i>Marine</i> yellow limestones and shales, fossiliferous. Bugti beds of Baluchistan, <i>fresh water</i> in origin with mammalian remains.</p>	<p>Lower Miocene.</p>
	<p>Upper Nari—sandstones, unfossiliferous, <i>partly of fluvial</i> origin. Lower Nari—<i>marine</i> limestones,</p>	<p>Oligocene.</p>

Kirthar series 3000 to 9000 ft.	fossiliferous.	Massive Nummulitic limestones forming the higher ranges of Sind, fossiliferous, <i>marine</i> .	Middle and Upper Eocene.
Laki series 500 to 800 ft.		Carbonaceous and calcareous shales. Alveolina limestones.	Eocene.
Ranikot series 2000 ft.		Upper Ranikot series—fossiliferous limestones and shales. <i>Marine</i> . Lower Ranikot series—Gypseous and carbonaceous shales and sandstones. <i>Fluviatile</i> .	do
		Cardita Beumonti beds.	Cretaceous.

Himalayas.*Punjab and Kashmir
Himalayas*

- Upper Siwalik System:*
Boulder conglomerates,
sands, clays and grits.
Middle Siwalik System:
Massive grey sandstones
and shales.
Lower Siwalik System:
Bright red shales, grey
and brown sandstones.

*Kumaon and Simla
Himalayas.*

- Upper Siwalik System:*
Clays and Boulder con-
glomerates.
Middle Siwalik System:
Sand-rock, clays and
shales.
Lower Siwalik System:
Grey micaceous sand-
stones and red shales.

Mid. Miocene
to Pliocene.*Murree Srs.:*

Soft and hard sand-
stones, purple coloured
shales.

Fatehjang beds:

Sandstones and pseudo-
conglomerate.

Kasauli Srs.

(*Lacustrine*) Grey or
green sandstones.
Dagshai Srs. (Lagoon)
Bright red clays and
sandstones.

Lower Mio-
cene.

<i>Chharat srs.:</i> Nummulitic shales, limestones and marls.	<i>Sabathu srs.:</i> Grey and red shales and Nummulitic lime- stone.	Eocene.
<i>Lower Nummulitic lime- stones.</i>		
The Salt-Range.		
Up. Siwalik	Boulder conglomerate, conglome- rates, sandstones and clays.	Middle Mio- cene to Plio- cene.
System	Shales and sandstones.	
Mid. " "	Hard dark coloured sandstones.	
Lr. " "	Purple shales and pseudo-conglo- merate.	
Unconformity	
Kirthar Srs.	Massive Nummulitic limestone.	Eocene.
Laki Srs.	Clays, shales and Coal Mea- sures.	

For the convenience of students, *marine Tertiary rocks of Sind* may be described as follows :—

The Ranikot Series.—It lies conformably over the Upper Cretaceous rocks of Sind. It consists of sandstones, carbonaceous calcareous and lignitic shales, and limestones. The limestones are highly fossiliferous containing Echinoids—*Cidaris*, *Salenia*; Corals—*Stylina*, *Isastræa*; gastropods—*Rostellaria*, *Nerita*; Foraminifera—*Nummulites*. *N. Planulatus* is characteristic.

Age of the Ranikot series is Lr. *Eocene*.

The Laki series.—It lies over the Ranikot series and consists of carbonaceous and calcareous shales. Coal is not found. Alveolina limestone occurs. Important fossils are foraminifera—*Nummulites* (*N. atacicus*), *Alveolina*; Echinoids—*Schizaster* and *Hemiaster*.

Age of the Laki series is Lr. *Eocene*.

The Kirthar series.—It lies over the Laki

series and consists of massive Nummulitic limestone many species of Nummulites are found of which *N. Lævigatus* and *N. Complanatus* are the most common. *Alveolina* is also found. The gastropods are found in large numbers of which *Conus*, *Cypræa* are very common. Echinoids—*Cidaris* and *Micraster* are common. Lamellibranchs are represented by a large number of genera e. g., *cardita* and *astarte*.

Age of the Kirthar series is Middle and Upper Eocene.

The Nari Series—It lies over the Kirthar series and consists of limestones bedded sandstones and shales containing fossils of Nummulites of which *N. Intermedius* and *N. Sublavigatus* are very common. Other fossils are Corals and Echinoids—*Schizaster* and *Breynia*; Lamellibranchs and Gastropods.

Age of the series is Oligocene.

The Gaj series. The Nari series is conformably overlain by the Gaj series and consists

of yellow limestones and shales. The series is characterised by the *absence of Nummulites*. The limestones are full of corals. The lamelli-branches are found in large numbers—*Ostrea* (*O. Latimarginata*), *Tellina*, *Echinoids*—*Clypeaster* and foraminifera—*Lepidocyclina* are found. The Age of the Gaj series is the Lower Miocene.

CHAPTER XIV

The Eocene System

The rocks belonging to the Eocene system are developed in the Extra-Peninsula in Sind, Baluchistan, the Salt-Range and the Outer Himalayas. They are divided into three divisions: the Ranikot, the Laki, and the Kirthar-series. Each of these series is named after the hill ranges where they are best developed.

The Ranikot series of Sind.—It is sub-divided into two series, the lower and the Upper. The lower one is of fluviatile origin containing dicotyledonous plants. The upper one is of marine origin and has already been described.

The Ranikot-series is developed in Sind, N. W. Punjab, and Pir-Panjal (Kashmir).

The Laki-series.—It is widely distributed. It is developed in Sind, N. W. Punjab (Chharat series), the eastern Salt-Range, Jammu and Baluchistan. It consists of shales and thin beds of coal. The salt, gypsum, anhydrite, and marl of the Salt-Range are of Eocene age. The shales at Dandot and Kalabag are pyritous and are source of alum. The fossils are foraminifera and echinoids. The marine Laki-series of Sind have already been described.

The Kirthar series.—These are widely distributed in Sind, Baluchistan, the Salt-Range and N. W. Frontier Provinces. It consists of Nummulitic limestone of white, greyish-pink colour, massive jointed containing large number of Nummulites and other foraminifera, gastropods, echinoids, and lamellibranchs. The marine Kirthar-series of Sind have already been given.

The Eocene rocks of the *Outer Himalayas*

are named as the *Sabathu series*. They are equivalent to the Laki-series of other areas and are named after Sabathu, a hill-station near Simla. They are composed of shales, sandstones, nummulitic limestones, and coal. They are developed near Simla and in Kashmir Himalayas. In the Jammu hills, near Riasi they consist of coal, ironstone, bauxite and limestone.

CHAPTER XV

The Oligocene and the Lower Miocene

The rocks of these two systems are developed in Sind, Baluchistan and the Outer Himalayas.

The Nari-series of Sind.—The series derives its name from Nari-river along the banks of which rocks are exposed. The marine Nari-series of rocks of Sind have already been described. The shales are interrelated with sandstones of upper Nari horizon which contain plant impressions of fluviatile origin. The age is Oligocene.

The Gaj-series.—The Nari-series are conformably overlain by the Gaj-series of Oligocene age.

The marine Gaj-series of rocks of Sind have already been described.

Baluchstan — The marine conditions prevailed from the Nari to the lower Gaj epoch. During upper Gaj period fluviatile conditions prevailed. The marine rocks resemble with those of Sind. The fluviatile rocks consist of sandstones containing vertebrate remains. The mammals are found in large numbers. The beds are known as the *Bugti beds*.

The Outer Himalayas

The rocks of the systems are composed of two series—the lower, the *Dagshahi series* are composed of bright red nodular clays and hard sandstones containing fucoid markings. Over the Dagshahi series lies the Upper, the *Kasauli series* composed of sandstone containing a palm, *Sabal major*. The rocks are very well developed in Simla area and Jammu Hills near Dharonthal.

In the outer Hills bordering the Jammu and Kashmir Himalayas the Dagshahi and the Kasauli series of Simla area are represented by sandstones and shales of reddish purple colour

and are known as the *Murree series*. They have been named as such on account of their typical development in the Murree Hills. Besides red sandstones and shales there are grey sandstones and nodular clays, and pseudo-conglomerates containing palm leaves—*Sabal major*. The Murree series conformably overlies the Sabathu series and underlies the Siwaliks. At Khaur, petroleum occurs in the Murree series of rocks which probably has migrated from the underlying rocks belonging to the Eocene System.

The outcrops of rocks belonging to the Middle Tertiary are met with in the Peninsula at a number of places e. g., the Coromandal coast, Cutch, Gujrat, Travancore and Kathiawar.

It may be pointed out that during the Oligocene and the lower Miocene periods the Extra-Peninsula was visited by igneous activity in the form of plutonic intrusives. In the Himalayas and Baluchistan large masses of granites, syenites, diorites, peridotites, etc. are found intruded into the Eocene, Oligocene and

lower Miocene rocks.

CHAPTER XVI

THE SIWALIK SYSTEM

Middle Miocene to Pliocene

The Siwalik system is the uppermost member of the Tertiary rocks of India. The name is derived from the Siwalik hills situated near Hardwar where the rocks were first studied. The rocks are of *fresh water origin deposited by rivers*. The rocks of the system are extensively developed in the Extra-Peninsula in the outermost hills of the Himalayas extending along the entire length from the Indus to the Brahmaputra, the important localities are Potwar Plateau in the N. W. Punjab, Simla Hills, Kangra, Jammu, the Salt-Range, Sind, Baluchistan and Assam. A fine section of the rocks is exposed along the road from Jammu to Udhampur. As we proceed from Jammu to Nandni we meet with older and older series of rocks as the rocks are dipping towards Jammu. There is a great fault, known as the *main*

boundary fault extending from Jammu hills to Assam hills representing an original limit of deposition of the sediment.

The lithological and palæontological characters of these rocks in these different localities are nearly the same though different names have been given e. g., Manchhar system in Sind.

The rocks of the system have been broadly sub-divided into three series—the lower, middle and the upper Siwalik series. The following classification is based on lithology (rocks). They also contain distinct fossils of their own.

Upper Siwalik System.	Grey fine soft sandstone, conglomerate, boulder bed, and red sandstone.	Pliocene.
Middle Siwalik System.	Coarse grained sand-rock of pepper and salt-grey colour, containing concretion, clay bed and pebble bed.	Upper Miocene
Lower Siwalik System.	Fine hard sandstone, red clay and concretionary conglomerate.	Middle Miocene.

There are large number of fossils of fresh water e. g., mollusca, fishes, tortoise, etc. which lived in rivers. The two important species of lamelli-brachs e. g., *Indonia mittali* and *Lamillidens Jammuensis* were discovered by the author in Jammu Hills. The vertebrate fauna is found in great abundance, especially the mammalia. The representatives of carnivora, proboscidiens, ungulates, primates, etc. are found in abundance. A reptile known as *colossochelys atlas* is also found which is considered to have attained about 20 feet length. The dicotyledonous leaves and tree trunks are also found buried in the rocks.

The rocks of the system as have already been mentioned are divided into three series on petrological and palæontological characters. The system is very rich in mammalian remains and a few of them may be given here :—

Upper Siwalik *Elephas hysudnicus*, *Elephas*
system. *planifrons*, *Stegodon ganesa*,
Simia, *Equus sivalensis*.

Middle Siwalik *Prostegodon cautleyi*, *Ste-*

system. godon clifti, Hipparion,
 Palæoppithicus.

Lower Siwalik Dinotherium, Tetrabelodon,
 system. Aceratherium, Sivapithicus
 indicus

CHAPTER XVII

THE QUARTERNARY ERA

The Peistocene and the Recent

There are two important events which mark the Quarternary era. In the lower part of the era, the climate of the northern part of the Northern Hemisphere went so low that a greater part of it was covered up with a thick mantle of ice and snow. The northern Europe, North America, and Asia presented the same appearance as we find to-day in Greenland. To this part of the Quarternary era the name of *glacial period*, *Glacial age* or *Pleistocene* is given. The existence of such an Ice age is proved by the records left by ice e. g., polished and striated pebbles and boulders, Rochee moutonnees, perched blocks, etc. During this time many kinds of antarctic

animals and plants lived in Central Europe and their remains are found in the deposit of this period. The principal animals are woolly rhinoceros, mammoth, reindeer, etc. By the lowering of temperature the countries situated on much lower altitude were also effected, for example the glaciers of the Himalayas and the Alps were more extensive than at present and left their records at much lower altitude. In the upper part of the era man appeared. This part of the era, is called the *Human period or Recent*.

The Quarternary era in India

In India also there existed a glacial age. There was a general lowering of the temperature of the plains of India. The snow-fields of the Himalayas spread farther than usual and gave rise to far more extensive glaciers than at the present day.

We do not find any record in the form of perched blocks, glaciated boulders, etc. in the plains of India but the cold climate of the time has certainly left its marks on the fauna and flora of the country. The existence of Himala-

yan Plants on Mount Abu, Aravalli-range, Nilgiri, Animale, Shivrai clearly points to a general lowering of the temperature. The existence of the Himalyan goat e. g., *Capra Halocrius* on the Nilgiri and Shivrai Hills is another proof to the same effect.

There are various kinds of deposits in India belonging to the Pleistocene and Recent systems which may be given briefly as follows:—

(1) **The Indo-Gangetic Alluvium.**—This plain lies between the Peninsula and the Extra-Peninsula. It is one of the *world famous alluvial plain* covering an area of 300,000 square miles with an unusually great thickness. It is wholly composed of river alluvium—sand, clays, silt, gravels, etc. All boring attempts to reach the bottom-rocks have failed so far. The solid geology of the region has been concealed by a thick mantle of river alluvium. The older part of the alluvium is known as the *Bhanger* which also contains lime-*Kankar* which is a great source of lime and cement. The

newer part is comparatively recently formed alluvium and is known as *Khaddar*. In the older alluvium remains of extinct elephants, rhinoceros and hyppopotamus are found but in the newer alluvium remains of living animals and plants are found.

The Indo-gangetic alluvial plain seems to have undergone an earth-movement during Pleistocene times since a large part of this plain is found far above the height even reached by the highest floods of the Ganges and other rivers draining the area.

(2) The Rajputana desert

Another deposit of Pleistocene or of more recent age is the great mantle of sand covering the whole of Rajputana. The thickness of the sand is very great giving rise to sand dunes with a few rocky projections of low elevation. The rocky projections have been greatly polished on account of æolian action. The sand is the result of disintegration of rocks by alternate heat and cold. A few oases are also found at places.

(3) **Laterite.**

A large part of the Peninsula is covered up with a peculiar rock known as *laterite*. It is brownish or reddish in colour. It is massive or vesicular in structure. It is essentially composed of hydrated oxide of aluminium (Bauxite) and limonite—hydrated oxide of iron with a few impurities of manganese oxide. It is used as an ore of aluminium, iron and manganese and also as a building-stone. It is produced by the subærial decomposition of the crystalline rocks of the Peninsula under peculiar monsoonic climates prevailing there.

(4) **Karewas.** These are composed of silt, clay, sand and gravel. These are found in the Kashmir valley. Part of the Karewas are of Recent formation by the river Jhelum, but there is no doubt that nearly half of it is composed of older alluvium forming mounds sloping away from the high mountains. Most of the Karewas are horizontally bedded. The Karewas, in their upper beds are supposed to be the remnants of an old large lacustrine formation

which once filled the whole of valley of Kashmir to a depth of about 1000 feet. These Karewa mounds have been produced by the subærial denudation and by the river Jhelum. Impressions of leaves and fresh water mollusca are found.

(5) **Another Pleistocene or Recent deposit is the Porbunder stone (Miliolite)** occurring along the coast of Kathiawar. It is composed of wind-blown calcareous sand—*foraminifera*.

(6) **Loess**—A loose clayey sandy-rock known as loess is found lying at the foot of the hills of the Salt-Range and N.W. Punjab. The Loess deposits are found near Musakhail, Mianwali district in the Punjab.

(7) **Fluvio-glacial deposit of Potwar-plateau** is an example of Recent deposit (8) Some of the *raised beaches* along the coasts of India at about 100 feet height are probably of Pleistocene age.

CHAPTER XVIII

Economic Geology of India

The economic products of India may be described briefly under the following headings :—

(1) Metals and ores, (2) Precious and

Semi-precious stones, (2) Economic mineral products, (4) Lime and cements, (5) Building stones, (6) Clays and sands, (7) Peat, coal and petroleum.

METALS AND ORES

Gold.

The most important mine where gold is found in large quantity is the mine of *Kolar gold field* in Mysore state. Native gold here is found scattered in grains in quartz veins traversing the hornblende schists of Dharwar system. The other gold-fields are of Hyderabad state and Anantpur of Madras which are not so important. The production of gold in 1938 was about 321, 138 ozs.

Manganese.

India is the second largest producer of manganese of the world. The principal deposits of the ore are found in the Central Provinces. The ore is also found in Behar, Orissa, Madras, States and Bombay Presidency. The important deposits are found associated with Dharwar system of rocks. The production of manganese ore in 1938 was about 992, 795 tons.

Iron.

Behar and Orissa are the largest producer of iron ores in India. The ore is extensively developed in Singhbhum and the adjacent Eastern States. It is also found in Mysore State (Bababudan Hills), Salem and Madura. Workable deposits are also found in Central Provinces (Chanda and Jabalpur districts).

The iron ores are found associated with the Lower Gondwana system of rocks of Bengal and Archæan, Dharwar and Cuddapah rocks in the Peninsula. Production of the ore in 1938 was about 2, 743, 675 tons.

Copper.

Copper is mined and smelted in Singhbhum, Behar. Small deposits of the copper ore are found in Bengal, Assam, Behar, Central Provinces, Central Indian States, Garhwal, Jammu and Kashmir, Mysore, Rajputana and Sikkim. *Singhbhum is the most Important locality* for copper production in India. Here chalcopyrite occurs in lodes associated with

Dharwar phyllites and schists.

Aluminium.

The Chief source of aluminium in India is Bauxite—Hydrated oxide of aluminium. The important deposits are found in *Behar, the Western Ghats* and Central Provinces. The deposits are widely scattered and are also found in Bhopal, Palni hills, Kalahandi State, Riasi in Jammu State. In 1938 production of Bauxite was about 14, 768 tons.

Tin.

Cassiterite (*dioxide of tin*). It occurs in small quantities in Palampur and Hazaribagh.

Chromium.

Chromite (oxide of chromium). Important deposits of chromite are found in dunites and serpentine rocks in Baluchistan, Bihar (Singhbhum), Mysore and Keonjhar. In 1938, production of the ore was about 44, 149 tons.

Lead.

No workable lead ore deposit is found in

India. The only deposits which are found in India are of Zewar in Mewar, Rajputana and Jaipur State.

Zinc.

Zinc blende (Sulphide of zinc) occurs in small quantity in Udaipur, Rajputana, and Riasi, Jammu State.

Silver.

It is obtained from Kolar-goldfield in Mysore State.

Antimony.

Small deposits of stibnite (Sulphide of antimony) occurs in Chitral and Lahaul (Spiti).

Arsenic.

The chief ores of arsenic are orpiment and realgar (sulphide of arsenic). Orpiment is found in small quantity in foliated masses in *Chitral*. Kumaon is the next important locality.

(2) Precious and semi-precious stones.

Diamonds. (Pure carbon).

They occur in two conglomeratic beds, belonging to Vindhyan system. They occur in the form of rolled fragments and they are believed to have been derived from the dykes of Bijawar series of Cuddapah system. The famous *Golconda diamonds* were obtained from Karnul district and Panna diamonds from Bundelkhand.

Aquamarine (Silicate of beryllium and aluminium).

The chief source of Aquamarine is the mica bearing pegmatite of Coimbatore district and Kishangarh state in Rajputana. It is also found in Behar, Nellore and Kashmir.

Sapphires. (Aluminium oxide).

Sapphires were obtained from felspathic gneisses of Kishtwar district in Kashmir State.

Tourmaline. (Boro-silicate of aluminium, etc.)

Green coloured tourmalines are found in Sapphire mines in Kashmir State and Hazari-

bagh.

Zircon. (Silicate of Zirconium).

India is an important source of zircons. It is obtained from the sands of Travancore.

Garnet. (Ortho Silicate of aluminium, calcium, magnesium, iron, manganese, etc.) Garnets are found in micaschists of Jaipur State, Udaipur State and Kishangarh State.

Kyanite. (Aluminium silicate).

The largest deposit of India is found at *Lapsa* *Buru* in Kharsawan State.

Apatite. (Fluoro or chloro phosphate of calcium).

It is found in pegmatites of Ajmer in Rajputana, and Vizagapatam in Madras Presidency.

(3) **Economic mineral Products.**

Rock salt. (Sodium chloride).

There are three sources of salt in India,
(1) from sea water near Bombay and Madras,

(2) from **Sabmhar lake** in Rajputana and
(3) Rock-salt of the Salt-Range, Punjab of
Kohat and *Khehra* belonging to Saline series of
lower Tertiary age.

Saltpetre or Nitre. (Potassium nitrate).

It is found as a saline efflorescence on the
surface soils of *Behar*, Sind and the Punjab.

Alum. (Hydrated sulphate of potassium
and aluminium).

It is manufactured from pyritous shales of
Kalabagh.

Borax. (Hydrated borate of sodium).

It is found in the Puga Valley of Ladakh.

Iron pyrite and Sulphur. (Iron pyrite is
Sulphide of iron).

Iron pyrite is considered a source of sulphur.
It is obtained from pyritous shales of Kalabagh.
Pyrite is also obtained in Behar, Simla Hills and
Dandot (Punjab). Native sulphur is obtained
from Kashmir State and Baluchistan. Sulphur

can also be obtained from the gypsum of the Salt-Range.

Phosphates.

These are found in Trichinopoly district of Madras Presidency and in Singhbhum in Behar.

Gypsum. (Hydrated sulphate of calcium).

The most important deposit of gypsum in India is that of the *Salt-Range* in the Punjab. Gypsum is also found in Bikaner, Jodhpur, Jaisalmer, Garhwal, Kashmir and Jammu.

Talc. (Hydrated silicate of magnesium).

Talc deposits of immense thickness are found in Rajputana and Madras but they are also found in Central Provinces, United Provinces, Central India, Behar, and Mysore.

Magnesite. (magnesium carbonate).

The most important deposits of magnesite of India are found in Madras and Mysore State.

Asbestos. (Silicate of calcium, magnesium)

and iron).

Asbestos deposits of India are small and are found in Madras, Seraikala and Mysore State.

Barytes. (Barium sulphate).

Barytes is the most important source of Barium. It is worked in Madras, Alwar, Behar, United Provinces and Jammu State.

Corundum. (oxide of aluminium).

It is obtained from Madras Presidency, and Zanskar ranges of Kashmir.

Mica. (Muscovite is Hydrated silicate of aluminium and potassium).

Muscovite, the white mica is used in industries. India is the largest producer of mica in the world. Workable deposits of it are found in pegmatites of Behar, Madras, Bengal and Rajputana. Behar mica deposit is the most important.

Monazite. (a phosphate of cerium, lanthanum, didymium with a little thorium).

It is obtained from Monazite-ilmenite-sands and pegmatites of Travancore.

Ilmenite (Titanium oxide of iron).

It is obtained from mica-pegmatites of Behar and Orissa and from ilmenite-sands of Travancore.

Zircon. (Silicate of Zirconium).

It is mainly obtained from beach-sand of Travancore.

(4) **Lime and cements.**

Workable deposits of limestone for cement making are available in the Salt-Range, Punjab, United Provinces, Central Provinces, Rewah, Baluchistan and Jodhpur in Rajputana.

(5) **Building stones.**

A large number of rocks in India are used as building stones which may be given as follows :—

(1) Some of the Archæan gneisses of the Peninsula e. g., the Arcot gniess.

Upper Vindhyan sandstones are largely used for building purposes. Murree sandstone is also used locally for the same purpose.

(3) Cuddapah, Bijawar and Aravalli groups of limestones of the Peninsula, Vindhyan limestone of Central India, Nummulitic limestone of the Salt-Range (Punjab) are used for building purposes.

(4) Marbles of great beauty are found in India, most of them come from the Aravalli series of Rajputana at a number of places, near Jodhpur, Jaipur, Ajmere, and Alwar.

(5) Slates are quarried at a number of places e. g., Kangra and Rewari of the Punjab, Ramban of Jammu State, Almora and Garhwal of the United Provinces.

(6) Deccan Trap of South India and Punjab Traps of Kashmir.

(7) Laterite of South India.

(8) Quartzite of Jammu State.

(6) **Clays and Sands.**

Workable China clay deposits are found at

Singhbhum and Keonjhar.

Fire clays are found in Rajmahal Hills of Bengal, and Central Provinces.

Clays of bentonite type are found in Jodhpur, Rajmahal Hills and Jammu and Kashmir.

Fullers earth deposits are extensively found in Jodhpur, Jaipur, Jaisalmer, Bikaner and Sind.

Common clay is found in great abundance in the alluvial plains of the Punjab, United Provinces and Bengal. It is used for making bricks.

Sands.

Suitable sand for glass-making is found near Naini in the United Provinces, Baroda State and Bikaner State.

Magnetite-sand, ilmenite-sand and monazite-sands of Travancore and gem-sand of Ceylon are of great economical importance.

7. Peat, coal and Petroleum.

Workable **Peat** deposits are found in the

delta of the river Ganges, in the alluvium of the river Jhelum in Kashmir Valley, in the Nepal valley and the Nilgiri Hills in South India.

Coal.

Is a very important mineral product of India. It is found in the rocks of Lower Gondwana system in South India and the lower Tertiary rocks of the Extra-Peninsula. It is found in Behar, Western Bengal, Central India, Central Provinces, Hyderabad State and the Punjab.

Petroleum.

In India it is found in the Punjab (Khaur oil-field) and Assam. Here petroleum is found associated with the Tertiary system of rocks.



CHAPTER XIX

Economic Geology of Jammu and Kashmir State

For our purpose the various useful products which the rocks and minerals of Kashmir State yield, can be classified as follows:—

(1) Metals and ores, (2) Precious and semi-precious stones, (3) Building stones and road metals, (4) Sands and clays, (5) Peat, lignite, and coal, (6) Other economic minerals and mineral products.

(1) Metals and ores

Antimony.—Pockets of antimonial lead are found at a number of places e. g., Riasi, Kotli, Ramnagar and Kishtwar Tehsils.

Arsenic.—Orpiment (tri-sulphide of Arsenic) of fine lemon yellow colour is found at Lingh-shot Kargil. Arsenopyrite (sulphide of arsenic and iron) of white colour is found in Paddar area. Both of them are used as ores of arsenic.

Barium.—Barytes is Barium sulphate. It is found in sufficiently large quantity in pockets in the Great limestones in Reasi area especially at Jungal Gali, a few miles from Tikri. It is of very good quality.

Barytes is used in the manufacture of white paints.

Aluminium.—Extensive deposits of bauxite (hydrated oxide of aluminium) are found in association with the Nummulitics of Jammu and Poonch. Bauxite passes downward into bauxite clay and Kaolin. Diaspore is also found in great abundance. Both Diaspore and Bauxite are very rich in the contents of alumina.

Uses.—Aluminium is of great commercial importance. It is used for utensils. It is of great utility in electricity, metallurgy, æronautics. Bauxite can also be used for cement making.

Chromium.—Chromite (oxide of chromium and iron) is the chief ore of chromium which occurs as a product of magmatic differentiation in the form of segregation masses and veins in

ultrabasic dunites of Dras, Bambat and Telhgam areas of Kargil.

Chromite can be used for the manufacture of refractory bricks for furnace linings. Chromium can also be extracted from it. It is also used for the manufacture of mordants and pigments.

Copper.—Malachite (hydrated carbonate of copper) of rich quality is found in sufficiently large quantity at Banihal, Jammu Province. Sulphidic ore of copper is found at Lishtial and Kangan in Kashmir Province and Gainta and Kishtwar in Jammu Province. Native copper is found in Zanskar area and also in the bed of the Zanskar river. Native copper, chalcopryrite and malachite are important ores of copper. Copper is used for the preparation of utensils and in electric goods, coins, etc.

Gold.—Alluvial-gold is found in very small quantity in the terraces, and beds of the rivers—Drass, Suru and Indus. Auriferous pyrites are found in Shigar and Kargil areas.

Gold is used for making of coins and ornaments.

Graphite.—Amorphous graphite is found in Uri Tehsil, Batote-Khaleni area and Paddar. Foliated variety of Graphite of good quality is found at Bambyar Batote, and Ramban, Jammu Province.

Graphite is used for making of lead pencils, for paints, for crucibles, as a lubricant and for electro-plating.

Iron.—Clay iron stone occurs in very great abundance in the Nummulitics. Hæmatite (oxide of iron) of fair thickness is found at Rajouri.

Hæmatite is an important ore of iron. Iron in the form of steel, wrought iron and cast iron is used in commerce. Steel is used for the preparation of guns, armour plates, tools, rails, springs, etc.

Lead, Silver and Zinc.—Argentiferous galena (lead sulphide) of good quality is found at Buniyar in Uri Tehsil and at Nigote in Riasi Tehsil. Galena is found in Ramnagar, Kishtwār and Kargil Tehsils. Zinc blende

(sulphide of zinc) is found in Reasi Tehsil.

(2) Precious and Semi-precious stones

Ruby and Sapphire.—(oxide of aluminium). Ruby is of red colour and sapphire is of blue colour. Both the stones are found at Soomjam, Paddar (Kishtwar district) in highly fels-pathic gneiss. Sapphires were also obtained from the talus material at the foot of the hills.

They are used for ornaments.

Beryl.—(Silicate of beryllium).

It is found in Skardu and Paddar areas.

When it is transparent and green in colour, it is called aquamarine. It is found in abundance in Shigar valley in Skardu and also in Paddar. Crystals of large size and purity are also obtained from these areas.

Tourmaline.—Borosilicate of aluminium together with alkali metals, iron or magnesium.

Tourmaline of black colour occurs in the pegmatitic veins in Skardu, Kargil and Paddar

areas. Rubellite—red and Brazillian emerald—the green varieties are obtained from Soomjam in Paddar. They are used as gem stones.

Garnets.—Garnets are known to occur in Paddar area.

Fluorite.—It is calcium fluoride.

It occurs in Paddar and Ladakh areas.

Kyanite.—It is silicate of aluminium. It is of blue colour. It occurs in Paddar area and Skardu.

Quartz. It is silicon dioxide.

It is found in the crystalline rocks of Paddar, Kargil and Skardu areas. Rock crystals are used for cheap jewellery in Kashmir e g., for making necklaces.

(3) Building stones and Road metals

The Great limestones, Punjal trpas, Murree sandstones and Jammu quartzites are used for road metal.

The Great limestones and Nummulitic limestone are found in abundance in the State which are used for building purposes. Besides these, marbles are found in several parts of the State. Bararipur and Soonmarg marble deposits are important. Dolomite (carbonate of calcium and magnesium) is used as a building stone and is found in Great limestone in Jammu Province, Punjal traps in Kashmir are also used for building purposes, though their colour is not attractive. Slates of Ramban belonging to Dogra series are used for building purposes. Murree sandstones and granites found in various parts of the State are used for the same purpose.

(4) Sands and Clays

Sands occur in abundance in Upper Siwalik System of Jammu hills and Karewa deposits of Kashmir. Sands of good quality which can be used for glass making are found near Banihal, Jammu Province.

Clays of different kinds are found in great abundance in several parts of the State. Ordinary brick clay is found in Siwalik system of

rocks in Jammu hills and in Kashmir Valley and Karewa deposits of Kashmir. China clay or Kaolinite is found in pockets in the Great limestone underneath the Bauxite deposits of Reasi hills. Bauxite clay is also found here in abundance. China clay is of sufficient purity and can be used for ceramic purposes. Clays of bantonite type are found in the Siwalik system of Jammu. Bantonite is found in abundance at Parmandal and Bhimbar, Jammu Province.

(5) Peat, lignite and coal

Peat is not found in the State but lignite is found in abundance in the Karewas of Kashmir. Lignite deposits of Nichahom and Shaliganga are especially noted for quantity and good quality of the lignite. Coal of semi-anthracitic type is found in very large quantity occurring over wide area in the Sabathu series of rocks in Jammu Province. This belt of coal stretches from Jungal Gali to Poonch and is being worked at a number of places e. g., Kalakot, Gungal Gali and Reasi.

The coal at Reasi is thick but is not of

very good quality but the Kalakot coal is of good quality.

(6) Other economic minerals and mineral products

Alum shales.—The pyritic shales of the Sabathu series of Jammu Province on alteration give rise to alum shales. Alum is also found in the Puga Valley, Ladakh.

Asbestos.—It is a fibrous variety of amphibole. It is found in the crystalline rocks of Kargil and Paddar areas. It is used for making fire proof cloths and safes.

Borax.—It is hydrated borate of sodium. It is white in colour, soft to touch and of low specific gravity. It is obtained in the Puga Valley of Ladakh, Kashmir. It is deposited from hot springs associated with sulphur deposit. It is also obtained from the salt lakes in Tibet.

Corundum.—It is oxide of aluminium. Sapphire corundum is found in felspathic gneiss of Kishtwar area.

Gypsum.—It is hydrated sulphate of calcium. The massive variety known as alabaster is found in large quantity at Bambyar, Batote, Baggar and Ramban, Jammu Province. Gypsum is used for the preparation of Plaster of Paris.

Micas.—Muscovite (silicate of aluminium, potassium, and hydrogen) is of white colour and Biotite (silicate of magnesium, aluminium, potassium and hydrogen with iron) is of black colour. Micas are found in Paddar, Karnah, Kargil and Skardu areas.

Muscovite is of great importance in the electrical industry for insulating purposes in electrical apparatus. It is also used in the manufacture of lubricants, wall-finishes, rubber tyres. Powdered mica is used to give the frost effect on Christmas cards.

Nitre.—Small patches of nitre encrustations are met with in Kandi area of Jammu Province.

Phosphates.—Phosphatic nodules are found in abundance in the Karewa deposits of

Kashmir. They are used as manure.

Ochre.—Ochre deposits are found at Nurkhua and Jhuggi areas in Uri Tehsils and at Ratasar in Kashmir.

Common Salt.—It is sodium chloride. It is found in the marshes or dried up lakes of Ladakh area.

Talc.—It is hydrated magnesium silicate. It occurs in pockets in the Great limestone formation in Jungal Gali.

Talc is used as a filter for paints, paper, rubber, and lubricants, for removing grease from cloth, in leather making and toilet powder.

Syllabus of Indian Geology of the Intermediate Examination Of the Punjab University for 1945-1946

An elementary description of the development of the Archæan, Dharwar and Cuddapah of the Indian Peninsula; Vindhyan of Central India; Cambrian and Productus limestone of the Salt-Range; the Carboniferous and Permian of Kashmir; Trias of the Salt-Range; Spiti Shales and Jurassic of Cutch; Cretaceous of South India, the Deccan Trap; Lower Gondwanas; Marine Tertiary of Sind; the Murree series; the Siwaliks and the Indogangetic alluvium.

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University Questions

The following are the questions on Geology of India which were set in the Intermediate Examination of the Punjab University:—

1936

Give an account of the Geology of one of the following:—

- (a) The Cretaceous rocks of Southern India.
- (b) The Permo-carboniferous rocks of the Salt-Range.
- (c) The Eocene rocks of the Extra-Peninsula of India.

1937

1. Either describe the geology of any area that you have visited or give an account of the Jurassic rocks of the Indian Peninsula.

2. State what you know of the fauna of the Siwalik System of rocks.

1938

1. Either (1) give an account of the Gondwana system of rocks or (2) State what you know of the fauna of the Indian Trias.

2. Describe the Cretaceous rocks of Southern India. Where do rocks of this age occur elsewhere in India.

1939

1. Either (a) write what you know of the Siwalik system of rocks,

Or

(b) Give an account of the Geology of any area that you have visited.

2. State briefly the general characteristics of the fauna of the Palæozoic group of rocks.

Give a short account of this group of rocks as developed in the Salt-Range.

1940

1. Describe briefly the Tertiary systems as developed in Sind.

2. Either (a) write what you know of the Gondwana system, *or* (b) Give an account of the Palæozoic rocks of Kashmir.

1941

1. State how the Peninsular area of India differs from the Extra-Peninsula in geological and physical characters.

2. *Either* (a) Write what you know of the Cretaceous rocks of South India, *or* (b) Give an account of the Vindhyan system of rocks.

3. (b) In what localities in India do marine strata of Cainozoic age occur.

1942

1. Give a general account of the Gondwana system.

2. Write what you know of the Tertiary rocks of India.

1943

1. Give an account of the Mesozoic rocks of India.

2. Name the area of geological interest that you have visited and give an account of your observations.

3. Describe the Palæozoic sequence as observed in the eastern part of the Salt-Range of the Punjab.

1944

1 Give an account of the Dharwar System of the Indian Peninsula.

2. Write what you know about:—

(a) Jurassic of Cutch.

(b) Cambrian of the Salt Range.

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